National Space Day Hackathon 2025

Department of Physics, Guru Nanak Dev University, Amritsar

Problem Statement Booklet

Problem: The Chandrayaan-4 Lunar Outpost Mandate

Event Date: August 20, 2025

Organized in celebration of India's historic Chandrayaan-3 landing.

Event Schedule & Welcome

Welcome, future scientists and engineers, to the National Space Day Hackathon 2025! Today, we commemorate India's incredible achievements in space exploration by challenging you with a problem that reflects the real-world complexities faced by our nation's space program.

Your mission is not just about coding; it's about analytical thinking, strategic decision-making, and scientific rigor. Good luck!

Hackathon Timeline (3 Hours Total)

Event Flow

- **00:00 – 00:15 (15 mins): Briefing & Setup**
  Problem statement distribution. Teams may set up their development environments. The datasets will be made available via the provided link.
- **00:15 – 02:45 (2.5 hours): Coding Phase**
  The main hacking period. Teams will analyze the datasets, develop their algorithms, and determine the optimal pair of sites and the connecting path.
- **02:45 – 03:00 (15 mins): Final Submissions**
  Teams must finalize their code, push it to their GitHub repository, and submit their final output file via the submission portal.
- **Post-Hackathon: Judging & Results**
  The judging panel will evaluate all submissions based on the official marking scheme.

Dataset & Submission Portals

The required '.csv' data files and the submission portal will be available on August 20, 2025, at:

https://gndu-physics.github.io/nspd25.html

Your final code must be pushed to your team's GitHub repository within the last 15 minutes of the hackathon.

https://github.com/gndu-physics/

1 Problem Statement: The Chandrayaan-4 Lunar Outpost Mandate

1.1 Mission Directive

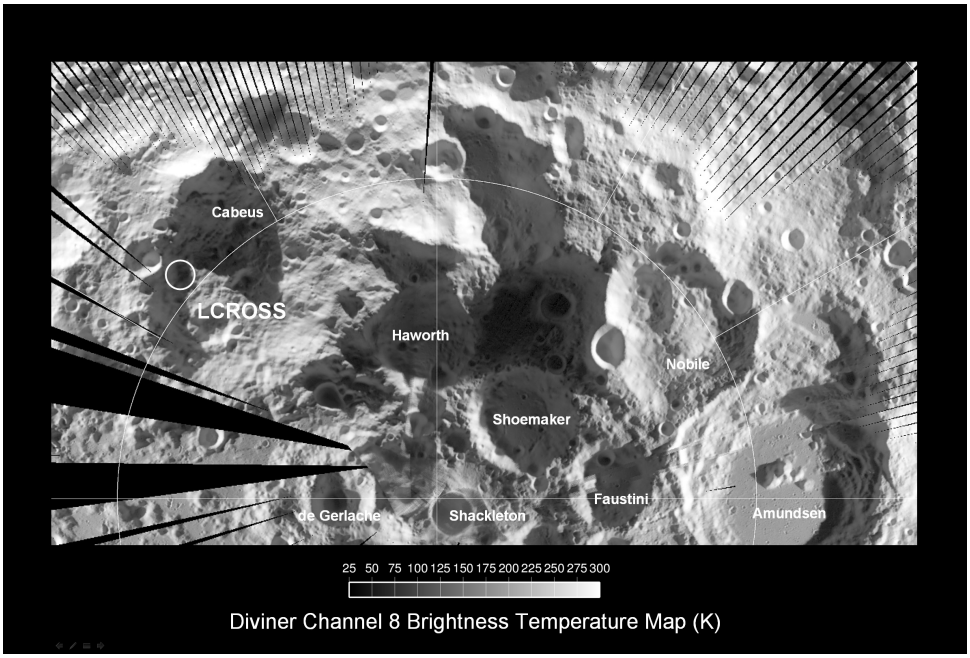
Official Communiqué

To: Mission Operations Complex (MOX), ISTRAC
From: Chandrayaan-4 Mission Directorate
Date: August 20, 2025
Subject: Critical Mandate: Optimal Site Selection for a Two-Part Lunar Research Outpost.

1.2 The Challenge: A New Paradigm

The establishment of a permanent lunar presence requires a dual-site strategy. A single location cannot satisfy the competing demands for constant solar power and access to water-ice. Therefore, your mission has been updated: you must identify an **optimal pair of sites** and a viable route between them.

1. **The Habitat Site:** A `5x5` cell area (`500m x 500m`) on a **Peak of Eternal Light**. This site must have the highest possible average solar illumination to power the outpost.
2. **The Mining Site:** A `5x5` cell area in a **Permanently Shadowed Region**. This site must have the highest probability of water-ice deposits for resource extraction.
3. **The Power Cable Constraint:** The two sites must be connected by a power cable. The path for this cable is constrained by terrain; the **slope** between any two adjacent cells on the path must not exceed a specific threshold (`MAX_SLOPE = 22`).



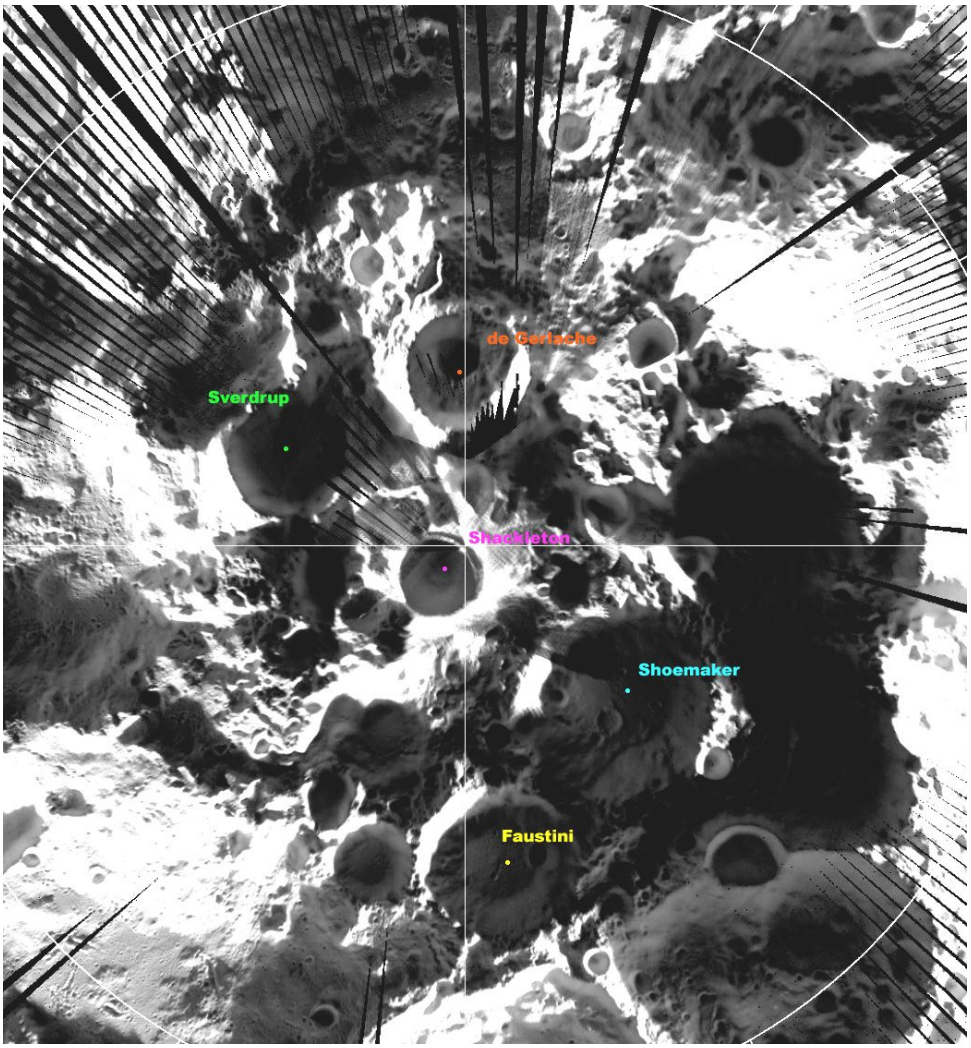
A topographical map of the lunar south pole, showing the complex cratered terrain.

The "optimal solution" is no longer a single point, but the pair of sites that provides the best combined scientific value (illumination and water) minus a penalty for the length of the connecting power cable.

1.3 Mission Parameters & Datasets

You will be provided with four CSV files representing a `500x500` grid (`50km x 50km`).

1. `elevation.csv`: Elevation in meters.
2. `illumination.csv`: Average solar illumination percentage.
3. `water_ice.csv`: Probability of subsurface water-ice.
4. `signal_occultation.csv`: Hours of communication blackout.



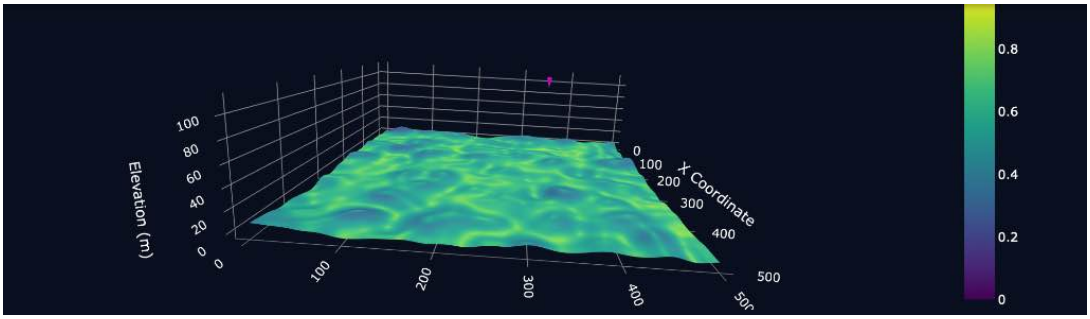
Actual landing site as imaged by Lunar Reconnaissance Orbiter (LRO).

2 Analytical Task & Final Objective

2.1 Your Analytical Task

Your program must implement a multi-stage analysis to solve this complex logistical problem.

1. **Site Identification:** First, you must identify a list of the most promising candidate sites.
   - **Habitat Candidates:** Search for `5x5` areas with the highest average illumination and low terrain roughness. Terrain roughness is defined as the standard deviation of elevation within the site.
   - **Mining Candidates:** Search for `5x5` areas with the highest average water-ice probability and low terrain roughness.
2. **Pathfinding:** For pairs of candidate sites (one habitat, one mining), you must implement a pathfinding algorithm to find the shortest possible path for the power cable. This path must adhere to the `MAX_SLOPE` constraint between every cell along its route.
3. **Combined Scoring:** The final score for a valid pair of sites is a weighted sum of the site qualities, penalized by the length of the connecting cable. The weights are **50% for illumination** and **50% for water-ice**, with a penalty of **0.001 per cell of path length**. Your goal is to find the pair of sites that maximizes this score.



Sample visualization of a lunar data set. (The data given to you are 90% replica of the real South Pole region and is not as shown in the image.)

2.2 Required Final Output

Required Final Output

Your final submission, uploaded to the submission portal, must be a single text file named `result.txt`. The contents of this file must exactly match the following format (including the text, spacing, and symbols), replacing the bracketed values with your results:

```
Optimal Pair Found with Combined Score: [e.g., 0.8123]

--- Optimal Habitat Site ---
> Coordinates (row, col): (e.g., 123, 456)
> Avg Illumination: e.g., 35.43%
> Terrain Roughness (Std Dev): e.g., 1.8765 m

--- Optimal Mining Site ---
> Coordinates (row, col): (e.g., 40, 150)
> Avg Water-Ice Probability: e.g., 0.5543
> Terrain Roughness (Std Dev): e.g., 1.1234 m

--- Power Cable Path ---
> Path Length: e.g., 50 cells (5000 m)

# Above values are just an example not the real values!
```

3 Official Marking Scheme

Total Points Available: 100

3.1 Functional Correctness (70 Points)

- **Final Output Accuracy (40 Points):**
  - Correct Coordinates and Scores for both sites: **20 points.**
  - Correct Path Length and Final Combined Score: **20 points.**
- **Algorithmic Logic (30 Points):** (For partial credit, assessed via code review)
  - Correct implementation of candidate site identification: **10 points.**
  - Correct and functional pathfinding algorithm that respects the slope constraint: **15 points.**
  - Correct implementation of the final combined scoring formula: **5 points.**

3.2 Code Quality & Implementation (15 Points)

- **Readability Structure (10 Points):** Well-structured, commented, and clear code.
- **Data Processing (5 Points):** Efficient use of libraries like NumPy or Pandas.

3.3 Performance & Efficiency (15 Points)

This category rewards teams who not only solved the problem, but did so efficiently.

- A brute-force search of all possible pairs will be too slow. Points are awarded for implementing an intelligent search strategy that prunes the search space (e.g., by only checking the top N candidates) to find the optimal solution in a reasonable amount of time.

4 General Rules Guidelines

1. **Team Size:** Teams can consist of 1 to 2 members.
2. **Permitted Languages:** Any programming language is permitted.
3. **Internet Access:** Internet access is permitted for documentation.
4. **Pre-written Code:** You may not use pre-written code that solves the core logic of this specific problem.
5. **Submission:**
   - The final `result.txt` output file must be uploaded to the **Submission Portal** before the deadline.

```
Optimal Pair Found with Combined Score: [redacted]

  --- Optimal Habitat Site ---
  > Coordinates (row, col): ([redacted])
  > Avg Illumination: [redacted]%
  > Terrain Roughness (Std Dev): [redacted] m

  --- Optimal Mining Site ---
  > Coordinates (row, col): ([redacted])
  > Avg Water-Ice Probability: [redacted]
  > Terrain Roughness (Std Dev): [redacted] m

  --- Power Cable Path ---
  > Path Length: [redacted] cells ([redacted] m)
```

Sample submission txt file.

   - Your team's complete source code must be pushed to your designated **GitHub repository** before the deadline.
6. **Academic Integrity:** All submitted work must be the original work of the team. The use of generative AI tools for creating the solution is strictly prohibited and will result in immediate disqualification. The decision of the judges is final.

Hackathon Coordinator Contact

For any technical issues with data access or clarifications, please contact the event coordinator. Coordinators cannot provide hints on how to solve the problem.

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Good Luck, and Happy Hacking!